Effect of Biofeedback on the Anxiety of Amateur Athletes

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Abstract

Biofeedback is an effective strategy to decrease levels of activation and anxiety. The purpose of this study is to determine the degree to which amateur athletes are able to learn to control their autonomic responses through biofeedback. The hypothesis of this study is that amateur athletes with biofeedback intervention will significantly decrease their level of psychophysiological activation compared to those without the intervention. Sixteen amateur marathon athletes participated, from the city of Andria de la Puglia, Italy. They were randomly assigned to two groups, one control and one experimental (i.e., biofeedback condition, which used peripheral temperature, skin conductance, and heart rate techniques). During the intervention period, there were six 15-minute individual sessions over two weeks. Anxiety was evaluated using the STAI survey, which is a subjective scale of activation and a psychophysiological profile. The statistical analysis used in this study is analysis of variance of repeated measurements was used with a significance level of .05. For the Post Hoc or a posteriori comparison, the Sidák and the Bonferroni procedure were conducted. A significant interaction was found between the evaluation conditions, timepoints, group, including peripheral temperature and in the skin conductance. The experimental group has significant lower activation compared to the control group, higher increase of the peripheral temperature and lower conductance. There is no difference in anxiety measured with the STAI. In conclusion, the biofeedback group has learned to control their autonomic responses, as indicated by a significant decrease in the level of psychophysiological activation, compared to the group without intervention.

Keywords: biofeedback, athletics, marathon, learning, intervention

1 Introduction

An emotional response can occur during any situation in life and can benefit or harm one's ability to function. During sports in particular, emotions present themselves often, and those emotions can enhance or hinder the performance of athletes. In pre-competitive moments, a series of emotions are generated (Donachie, Hill, & Madigan, 2019; Šniras & Ušpurienė, 2018), anxiety being one of the most researched in the field of sports psychology. If anxiety is not controlled, it can lead to coordination problems (Weinberg & Gould, 2010), as well as increase muscle fatigue due to its influence on the increase of lactate (Draper et al., 2008). It can also impair sports-competitive performance later on (Castro et al., 2018; Cintineo & Arent, 2019; Correia & Rosado, 2019; Garcia-Mas et al., 2011; Mabweazara, Leach, & Andrews, 2017; Pons et al., 2016). However, practicing sports can help individuals generate resources to manage and mitigate stress processes (Strahler et al., 2010).

One must consider that experience and skill level influence the positive perception of anxiety symptoms, which alone can be a facilitator in competition (Fletcher et al., 2012). In addition, exercise and, especially, aerobics are moderators of anxiety (de Miguel Calvo et al., 2011; Weinberg & Gould, 2010). In general, athletes can develop a resilient personality, which can act as a mediator of anxiety (Sheard & Golby, 2010). Such resilience is seen in athletes in events as challenging as long-distance running (De La Vega, Rivera, & Ruiz, 2011).

One can learn to develop a certain tolerance to stress for athletic competition through sports training, as proposed by Oudejans and Pijpers (2010). They propose that athletes practice with moderate levels of anxiety to facilitate adaptation to high levels of pressure in evaluation, or "game time," situations. One concern, however, is the medium and/or long term negative effect of protracted anxiety on the emotional well-being of the athlete and, therefore, on his or her motivation to continue (Cantón-Chirivella, Checa-Esquiva, & Vellisca-González, 2015).

However, the athlete can be offered an active role in learning to control his level of activation and, if necessary, his anxiety – in this case using biofeedback techniques. Biofeedback is defined as a set of

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psychophysiological procedures aimed at providing a person with immediate and accurate information about some aspect of his or her biological activity in order to learn to regulate or control it voluntarily. It is a psychological context of active learning by the individual (Vila & Guerra, 2009; Weinberg & Gould, 2010).

There are a number of empirical studies in which biofeedback has been used with athletes to control autonomic responses in a variety of situations, some of them related to anxiety or its consequences. Below, we present some research, for example, that of Contreras et al. (2017), in which they used galvanic skin response (GSR) biofeedback with a football goalkeeper, achieving increased relaxation (243 k in GSR), increased concentration, and decreased discouragement behaviours. Deschodt-Arsac et al. (2018) carried out biofeedback training with heart rate variability in university athletes over five weeks. There were two randomly-assigned groups (experimental and control) with positive results in autonomic control of the experimental group several weeks after the intervention. (Firth-Clark, Sütterlin, & Lugo, 2019), in a study comparing different cognitive-behavioral interventions (including heart rate variability biofeedback) in athletes at different skill levels, found improvements in the intervention groups compared to the control group. Dupee, Forneris, and Werthner (2016) used biofeedback and neurofeedback (electroencephalography) in five Olympic athletes to improve their self-awareness and emotional self-control, with positive results (breathing 8, heart rate 62 bpm, skin conductance 6.4 μS, peripheral temperature 35 ºC, and electromyography 2.5 μV). Rijken et al. (2016) employed heart rate variability biofeedback in professional soccer players and elite athletes, showing improvements (HRV soccer players LF/HF ratio 9.81, athletes LF/HF ratio 5.70) in their emotional control and optimization of their performance. Bar-Eli and Blumenstein (2004), studied two groups of students (one experimental group with typical training plus biofeedback and a control group with only typical training); the results indicated significant improvements in the performance of the biofeedback group. In another study by Bar-Eli and Blumenstein (2004) with elite swimmers, an experimental group received typical physical training sessions plus biofeedback and a control group received only typical physical training sessions; the results showed an improvement in the experimental group (running 5.17s, swimming 30.98s). Raymond et al. (2005), in a study with dancers, found improvements in performance evaluation for heart rate biofeedback (3.96 score) and neurofeedback groups (3.96 score); the control group had no change (3.84 score). Valiente and Ortís (1994) used heart rate biofeedback in cyclists; results showed a decreased heart rate and an improved performance. Caird, McKenzie, and Sleivert (1999) taught 7 long distance runners relaxation techniques and Biofeedback, which were applied to running on a treadmill for 6 weeks. The intervention from these techniques generated improvements in running efficiency of the participants (heart rate 157.86 ± 11.72 bpm, peak oxygen volume 53.03 ± 5.35 mL/kg/min and ventilation 78.80 ± 17.42 L/min). In a study by Pusenjak et al. (2015), high-level athletes in an experimental group of different disciplines including athletics learned to control their psychophysiological responses (skin conductance, heart rate, blood volume, heart rate variability and respiratory coherence) 15% better than the control group through 8 weeks of biofeedback training. They suggest that this improvement, which positively influences performance, is due to the learning of new skills including "learned self-regulation". The athletes also indicated that they applied these new skills in pre-competitive and competitive situations.

In some cases, biofeedback has also been used to treat or prevent injuries (Taylor et al., 2017). Edvardsson, Ivarsson, and Johnson (2012) conducted applied research with a cognitive behavioural intervention and biofeedback (galvanic skin response and heart rate variability) to reduce the number of sports injuries in school football players in Sweden; however, the results showed no significant differences between the two groups.

At a clinical level, applied benefits of the biofeedback technique have been observed in learning to control autonomic responses (peripheral temperature, blood volume, electromyography, breathing, etc.) (Kerson, Sherman, & Kozlowski, 2009; Nestoriuc et al., 2008; Pop-Jordanova & Chakalaroska, 2008).

When considering that excessive levels of activation and anxiety can diminish sports ability and that biofeedback has shown efficacy in the control of anxiety symptoms, questions remain about the utility of biofeedback as an intervention for anxiety reduction and performance enhancement among athletes, particularly developing athletes. The purpose of this study is to determine the degree to which amateur athletes are able to learn to control their autonomic responses and anxiety through biofeedback. Our hypothesis is that amateur athletes with biofeedback intervention will significantly decrease their level of psychophysiological activation and state anxiety compared to those without the intervention. The difference in this study is that the aim is to achieve benefits in a few sessions (6).

2 Methodology

2.1 Participants

The participants are16 amateur male athletes in the marathon (age M= 41.37 years, SD= 7.7, range 24-50 years. Height M= 176.5 cm, SD= 5.3. Weight M= 70.1 kg, SD= 5.9), from a village in southern Italy. They were randomly separated into two groups: a control group (ageM= 43.5 years, SD= 4.53) and an experimental group (ageM= 39. 25 years, SD= 9.80). Inclusion criteria were: absence of infectious disease, cardiovascular disease, metabolic disorder, had a minimum experience of two years of practice, training 4 to 8 hours per week and a minimum distance of 50 km per week. The Helsinki protocol was carried out. The athletes were explained the objectives, and they signed a consent form.

2.2 Instruments

- State-Trait Anxiety Inventory (STAI), Form Y (Spielberger, 1972), adapted to Italian. In correction the lowest direct score is 20 and the highest is 80.
- Biofeedback 2000 equipment, Schufried brand, with the Multi module with four channels: Skin conductance, peripheral temperature, heart rate and Motility. The equipment is wireless (bluetooth) with a range of nine meters.
- Subjective scale of activation level: 10-digit Likert scale, where 1 is the lowest activation level ("recently risvegliato" - recently awakened) and 10 is the highest activation level ("attachi di panico" - panic attack).
- Psychophysiological profile: The psychophysiological profile has been used as an evaluation tool for biofeedback interventions, which consists of recording physiological activity under different conditions (Carrobles & Godoy, 1987; Domínguez & Vázquez, 1999; Labrador, Cruzado, & Múñoz, 1995): (a) Rest: "Open Eyes" and "Closed Eyes", (b) Activation: may be the memory of an adverse or stressful situation and (c) Natural Relaxation Response: "Natural Relaxation." In this study, the following conditions were used: (a) Rest/Baseline (sitting eyes open), (b) Activation (standing imagining the finish line), and (c) Relaxation (sitting/relaxing with own strategies), each lasting two minutes (Ceccarelli et al., 2019; Estrada et al., 2012).

2.3 Procedure

Research Design:

The current study utilizes an experimental design with pre-test and post-test measures. Participants are randomly assigned to two groups, a control group without intervention and an experimental group (biofeedback).

Independent Variable: learning how to control the activation of autonomic responses using the biofeedback technique.

Dependent variable: anxiety level.

a) STAI questionnaire status version.
b) Subjective scale of activation level: Likert scale from one to ten.
c) Psychophysiological profile, measured by the following signals: Skin conductance measured in Micro Siemens (μS), with higher conductance indicating higher activation. Peripheral temperature measured in degrees Celsius (ºC), with lower temperature indicating higher activation. Heart rate measured in pulses per minute, with higher frequency indicating higher activation.

One of the authors was on a short research stay at the site and became interested in a short intervention program where the coach of the club's trainer also became interested. Due to the short time of the researcher's stay, a program of 2 weeks per participant was developed. Due to time constraints and the small size of the club, there were no more interested participants. One session was scheduled with the coach and another with the athletes explaining the details of the study (all signed an informed consent), the date of the evaluation was then determined. The pre-test evaluations were made one day before starting the sessions and the post-test one day after finishing the sessions. Pre- and post-test measurement consist of the following:

Connection of Biofeedback 2000 to the index finger of the non-dominant hand, with 4 minutes of adaptation (Blanchard et al., 1997). Completion of the STAI (State and Trait) and general questions. Recording of the psychophysiological profile, two minutes each condition - baseline (sitting), activation (standing, imagining the goal/exit), and relaxation (sitting, relaxing with own strategies). Subsequently, participants rated their level of activation with the Likert scale.

During the intervention period, there were six 15-minute individual sessions over two weeks.

In the study by Rijken et al. (2016) they used a minimum of 4 sessions to achieve benefits, meanwhile Raymond et al. (2005) consisted of six 20-minute sessions. The biofeedback program was structured as follows:

- 1st and 2nd session: Explanation of the biofeedback technique, emphasizing the individual's active process of learning, where concentration and attention are paramount. They were asked to individually choose words of relaxation and activation. Diaphragmatic breathing was taught for relaxation and an activation exercise (rapid breathing and imagination of energizing situation).

- 3rd and 4th meetings: Sitting biofeedback tests. Three one-minute relaxation tests and three one-minute activation tests (use of relaxation and activation words).
- 5th and 6th meeting: Standing biofeedback tests. Three one-minute relaxation tests and three one-minute activation tests (use relaxations and activation words).

We emphasize the 5th and 6th sessions, when biofeedback tests were performed by the standing athletes, as a transfer to the activity and the moment before a race begins, since in a long-distance race, the athletes cannot have a place to sit and relax to regulate their level of activation.

The post-test evaluation was conducted after the intervention.

Statistical analysis.

Repeated measures in an analysis of variance are used, with a significance level of .05, also used by Caird et al. (1999) and with 7 sample athletes. In these models it is necessary to assume that the variance-covariance matrix is circular or spherical. In contrast, there is Mauchly's (1940) test of sphericity, whose critical level associated with the W statistic (Sig.= .96) is greater than .05 (the hypothesis of sphericity is not rejected). In the event that the W statistic leads to the rejection of the sphericity hypothesis, it is possible to use the univariate F statistic by applying a corrective index called epsilon, in its two estimates: Greenhouse and Geisser (1959) and Huynh-Feldt, the former being the more conservative and therefore the one used. For the Post Hoc comparisons or a posteriori comparison, the Šidák (1967) procedure was used. Like the Bonferroni procedure, it is based on Student's t-distribution, but controls the error rate by evaluating each comparison with a significance level αc= 1- (1- α)1/k. This solution rejects the hypothesis of equality of means on more occasions than the Bonferroni method.

According to Fernández, Livacic-Rojas, and Vallejo (2007), the use of repeated measures statistics, homogeneity is covered by the random distribution of the groups in their formation and allows for a decrease in the variability of the experimental error, as the participants are their own control.

The statistical program used SPSS 20.0 for Windows.

3 Results

The descriptive statistics of the STAI and the subjective evaluation are shown below (see table 1).

Table 1

Means and standard deviation of the STAI and subjective activation

Groups	STAI				Subjective Activation	
	Trait		State			
	pretest	postest	pretest	postest	pretest	postest
Control	33.75 (5.77)	32.12 (5.46)	28.75 (5.59)	30 (6.96)	5.5 (1.51)	6.37 (1.5)
Experimental	32.12 (5.46)	36.37 (9.47)	30.12 (4.82)	31.75 (7.85)	5.12 (1.24)	4 (1.06)*

*p < .05

According to the data in Table 1, the means of the STAI are low (the minimum STAI score is 20 and the maximum 80). The STAI trait and state versions are similar in the pretest-post test evaluation and between the control and experimental groups; there is no statistically significant differences. The state version does not show differences between timepoints F(1,14)= 1.98, p= .181, power (1-β)= .58 (eta effect size squared of .12). There is no significant interaction effects among timepoints and groups F(1,14)= .03, p= . 857, power (1-β)= .50 (eta effect size squared of .00). The trait version presents similar results, with no differences in between timepoints F(1.14)= .41, p= .531, power (1-β)= .50 (eta effect size squared of .02), nor is there a significant interaction among timepoints and groups, F(1.14)= 1.05, p= .321, power (1-β)= .53 (eta effect size squared of .07).

In the subjective scale of activation level, there is no main effect differences, F(1,14)= .13, p= .71, power (1-β)= .99 (eta effect size squared of .71); however, a significant interaction is found among timepoints and groups, F(1,14)= 8.6, p= .011, power (1-β)= .89 (eta effect size squared of .38). In the pairwise comparison (Post Hoc), the experimental group has a lower level of subjective activation at post-test compared to the pre test (MD=1.12, p= .034) and compared to the control group (MD=2.37, p= .003).

Table 2

Means and standard deviation of psychophysiological responses.

Psychophysical response.	Groups	Sitting		Imagination Output		Relaxation	
		pretest	postest	pretest	postest	pretest	postest
Peripheral Temperature (°F)	Control	26.60 (4.06)	28.98 (4.71)	26.63 (4.15)	29.55 (4.05)	26.89 (4.12)	29.75 (3.75)*
	Experimental	26.25 (3.45)	29.69 (3.85)	26.42 (3.85)	30.68 (2.97)*	26.22 (2.88)	33 (2)**
Skin conductance (µS)	Control	2.89 (1.20)	2.13 (.70)	3.07 (1.22)	2.32 (.57)	3 (1.10)	2.20 (.78)
	Experimental	2.33 (1.18)	2.07 (.92)	2.63 (1.40	2.40 (.86)	2.92 (1.63)	1.40 (.50)*
Heart rate (bpm)	Control	105.75 (57.91)	68 (14.49)*	113 (54.93)	79.25 (27.74)*	99.25 (54.03)	65.87 (10.77)
	Experimental	101.25 (42.01)	65.12 (21.08)*	113 (40.10)	79.75 (25.46)*	106.87 (39.09)	68.12 (26.70)*

*p < .05, **p < .001

Table 2 shows the descriptive statistics of the psychophysiological responses at pre-test and post-test. The overall main effect test shows that the conditions (sitting, exit imagination, and relaxation) present significant differences in peripheral temperature, F(2,28)= 6.72, p= .015, power (1-β)= .84 (eta effect size squared of .32), in skin conductance (Mauchly's sphericity is accepted, Mauchly's W = .98, gl= 2, p= .888) F(2,28)= 5.93, p= .007, power (1-β)= .81 (eta squared effect size of .29), and in heart rate (sphericity accepted, Mauchly W= .78, gl= 2, p= .199) F(2,28)= 11.54, p <. 001, power (1-β)= .93 (eta squared effect size of .45).

In the pair-wise (post hoc) comparison, the output imagination condition has a higher level of psychophysiological activation compared to the sitting condition (conductance, DM= .24, p= .014; heart rate, DM= p= .012) and relaxation condition (conductance, DM= .21, p= .044; heart rate, DM= p= .001).

Significant interaction effects are found for timepoint by psychophysiological response: peripheral temperature, F(1,14)= 13.45, p= .003, power (1-β)= .95 (eta effect size squared of .49), skin conductance F(1,14)= 5.018, p= .042, power (1-β)= .78 (eta effect size squared of .26), and heart rate F(1,14)= 11.32, p= .005, power (1-β)= .93 (eta effect size squared of . 44).

In the pair-wise (post hoc) comparison, the pre-test evaluation has higher activation than the post test, with higher conductance (MD= .71, p= .042) and higher heart rate (MD= 35.5, p= .005).

There is a significant interaction between the assessment conditions and, the Pre-test and post-test evaluation. At peripheral temperature F(2.28)= 8.84, p= .003, power (1-β)= .89 (eta effect size squared of .38) and skin conductance (Mauchly W= .52, gl= 2, p= .014) F (2.28)= 4.38, p= .022, power (1-β)= .74 (eta effect size squared of .23).

In the intra-group pairwise comparison (Post Hoc), the control group has a lower level of activation at post-test than pre-test in the sitting condition (lower heart rate, MD= 37.75, p= .028), in the exit imagination condition (lower heart rate, MD= 33.75, p= .046), and in the relaxation condition (increased peripheral temperature, MD= 2.86, p= .046).

The experimental group shows a lower level of activation in at post-test compared to pre-test in sitting (lower heart rate, MD= 36.12, p= .034), standing (lower heart rate, MD= 33.25, p= .049; higher peripheral temperature, DM= 4.26, p= .009) and relaxation conditions (lower heart rate, DM= 38.75, p= .030; higher peripheral temperature, DM= 6.77, p < .001; lower conductance, DM= 1.48, p= .025).

However, in the inter-group comparison, the biofeedback intervention shows differences such that the relaxation condition at post-test has lower activation, associated with greater relaxation, compared to the control group, as indicated by an increase of peripheral temperature (MD= 3.24, p= .047) and a lower conductance (MD= .77, p= .036).

4 Discussion and Conclusions

In the STAI data, we find that there are no significant differences across timepoints or between groups. Trait anxiety, being a personality characteristic (Spielberger, 1972), does not appear directly in behaviour. (It can be reflected in the frequency of changes in state anxiety.) This varies little and is not possible to change in such a short time, and this seems to have influenced the lack of differences with state anxiety. It should be noted, however, that the mean scores are low overall, both in trait and state anxiety, which may be due to low trait anxiety. Given that the participants are long-distance, marathon runners who regularly engage in intense aerobic exercise (de Miguel Calvo et al., 2011; Márquez, 1995; Weinberg & Gould, 2010), their baseline trait anxiety levels may be lower due to the effect of their exercise regimen on anxiety, as well as the development of a resistant personality (De La Vega et al., 2011), which allows them to endure higher levels of stress.

However, in the activation level, we find that the experimental group, after biofeedback training, has a lower level of subjective activation at post-test compared to pre-test and especially compared to the control group.

For psychophysiological responses, we observe that the control group in the relaxation condition slightly increases its temperature after the imagination output condition, both in pre-test and in pos-test (the latter being significant). The experimental group also has a decrease in the level of activation in the post-test, in the baseline conditions, and in the relaxation condition, it achieves a significantly higher relaxation (increase of the peripheral temperature, decrease of the conductance and of the heart rate). Given that relaxation is significantly higher for the experimental group than the control group, it can be concluded that the experimental group has managed to learn to control their autonomic responses to relax via the biofeedback technique. These results are consistent with other applied research in which the biofeedback intervention trained participants to control their autonomic responses. In a study by Contreras et al. (2017), an increase in GSR was achieved (in the study, skin conductance was used) but with similar results, emotional control was achieved, the only difference being that it was done with individualized treatment. Similarly, Dupee et al. (2016) found improvements in athletes' emotional self-regulation and self-awareness, in addition to post-test values of peripheral temperature biofeedback, skin conductance and heart rate which are consistent with the current study's experimental group; a major difference being the current study took place for two weeks, and the previous study took place for one year. Our data are also consistent with Deschodt-Arsac et al. (2018) with regard to the benefits in self-control of the experimental group, with key differences in duration (prior intervention was five weeks) and measures used). Furthermore, results are consistent with Firth-Clark et al. (2019), although a key difference in the prior study was the combination of biofeedback and psychological techniques in the experimental group. Overall, the current results are consistent with the results of group biofeedback interventions (Bar-Eli & Blumenstein, 2004; Rijken et al., 2016). There is also agreement in part with the results of Caird et al. (1999) with respect to HR control, but that in their intervention there were other variables that control obtained which had a direct effect on the improvement of running performance (6 weeks in duration and with activities oriented to their activity level such as running on a treadmill) those of which unlike this research carried out few sessions with basic exercises. In turn, they agree with Pusenjak et al. (2015) in the control of GSR and heart rate achieved by learning new skills due to self-regulation, but it should be noted that the authors emphasize that for biofeedback to work after having been learned in the laboratory, it must create exercises designed as real as possible to the sporting activity. This last idea coincides with Blumenstein and Orbach (2014), and they have even proposed a series of 5 steps for the successful application of laboratory learning to sport competition.

In contrast, the current study's results are not consistent with studies by Edvardsson et al. (2012) and Kerson et al. (2009), which did not show significant differences related to the biofeedback intervention.

In general, the objective has been met, and the null hypothesis has been rejected. The biofeedback group has learned to control their autonomic responses and significantly decrease the level of psychophysiological activation, compared to the group without intervention. Although, there is no influence on state anxiety.

Learning to control autonomic responses provides individuals with strategies to cope with challenging or high-pressure situations that can impact performance. These positive effects are possible thanks to the relaxation achieved, as the athlete can rest better, improve their level of concentration, and increase their feeling of self-control. These learned strategies can be used in different areas, not only in sports, and can have a broad, positive impact on one's health.

With respect to suggestions for improving this type of intervention, we will consider evaluation situations related to a sports situation, to see the applied effectiveness of the intervention and an operational measurement of performance.

5 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6 Author Contributions

Conceptualization, E.C. and E.P..; methodology, D.P. and O.E..; software, C.D. and O.E..; validation, E.C., E.P. and D.P..; formal analysis, O.E.; investigation, O.E. and C.D.; resources, O.E., C.D. and D.P..; data curation, O.E. and D.P.; writing—original draft preparation, C.D. and O.E.; writing—review and editing, C.D. and O.E.; visualization, E.C., E.P. and D.P.; supervision, E.C. and E.P.; project administration, E.P and O.E. All authors have read and agreed to the published version of the manuscript.

7 References

Bar-Eli, M., & Blumenstein, B. (2004). The effect of extra-curricular mental training with biofeedback on short running performance of adolescent physical education pupils. *European Physical Education Review, 10*(2), 123-134. https://doi.org/10.1177/1356336X04044055

Blanchard, E. B., Peters, M. L., Hermann, C., Turner, S. M., Buckley, T. C., Barton, K., & Dentinger, M. P. (1997). Direction of temperature control in the thermal biofeedback treatment of vascular headache. *Applied Psychophysiology and Biofeedback, 22*(4), 227-245. https://doi.org/10.1007/BF02438978

Blumenstein, B., & Orbach, I. (2014). Biofeedback for Sport and Performance Enhancement. *Oxford Handbook Topics in Psychology*, 1-25. https://doi.org/10.1093/oxfordhb/9780199935291.013.001

Caird, S. J., McKenzie, A. D., & Sleivert, G. G. (1999). Biofeedback and relaxation techniques improve running economy in sub-elite long distance runners. *Medicine & Science in Sports & Exercise, 31*(5), 717–722. https://doi.org/10.1097/00005768-199905000-00015

Cantón-Chirivella, E., Checa-Esquiva, I., & Vellisca-González, M. Y. (2015). Bienestar psicológico y ansiedad competitiva: el papel de las estrategias de afrontamiento/Competitive Anxiety and Psychological Well-being: the Role of Coping Strategies. *Revista Costarricense de Psicología, 34*(2), 71-78. https://doi.org/10.22544/rcps.v34i02.02

Carrobles, J. A., & Godoy, J. (1987). *Biofeedback. Principios y aplicaciones*. Barcelona: Martínez Roca.

Castro, D. S., Cerdas, D. A., Barrantes-Brais, K., Bonilla, P. U., & Ureña, B. S. (2018). Autoeficacia, ansiedad precompetitiva y percepción del rendimiento en jugadores de fútbol categorías sub 17 y juvenil. *MHSalud, 15*(2), 36-54. http://dx.doi.org/10.15359/mhs.15-2.3

Ceccarelli, L. A., Giuliano, R. J., Glazebrook, C. M., & Strachan, S. M. (2019). Self-compassion and psycho-physiological recovery from recalled sport failure. *Frontiers in psychology, 10*, 1564. https://doi.org/10.3389/fpsyg.2019.01564

Cintineo, H. P., & Arent, S. M. (2019). Anticipatory salivary cortisol and state anxiety before competition predict match outcome in division I collegiate wrestlers. *The Journal of Strength & Conditioning Research, 33*(11), 2905-2908. https://doi.org/10.1519/JSC.0000000000003376

Contreras, O. E., Silva, C., Córdoba, E. P., Borrego, C., & Chirivella, E. C. (2017). Intervención directa mediante biofeedback, para cambiar las conductas de desanimo de un portero de fútbol. *Revista de psicología del deporte, 26*(2), 131-136. https://www.redalyc.org/pdf/2351/235152048017.pdf

Correia, M., & Rosado, A. (2019). Anxiety in athletes: Gender and type of sport differences. *International Journal of Psychological Research, 12*(1), 9-17. https://doi.org/10.21500/20112084.3552

De La Vega, R., Rivera, O., & Ruiz, R. (2011). Personalidad resistente en carreras de fondo: Comparativa entre ultra fondo y diez kilómetros. *Revista de Psicología del Deporte, 20*(2), 445-454. https://www.redalyc.org/pdf/2351/235122167014.pdf

de Miguel Calvo, J. M., Gallo, I. S., De las Mozas Majano, O., & López, J. M. H. (2011). Efecto del ejercicio físico en la productividad laboral y el bienestar. *Revista de Psicología del Deporte, 20*(2), 589-604. https://www.redalyc.org/pdf/2351/235122167023.pdf

Deschodt-Arsac, V., Lalanne, R., Spiluttini, B., Bertin, C., & Arsac, L. M. (2018). Effects of heart rate variability biofeedback training in athletes exposed to stress of university examinations. *PloS one, 13*(7), e0201388. https://doi.org/10.1371/journal.pone.0201388

Domínguez, B., & Vázquez, R. E. (1999). Autorregulación del estrés crónico. *Temas de Ciencia y Tecnología, 7*, 33–51.

Donachie, T. C., Hill, A. P., & Madigan, D. J. (2019). Perfectionism and precompetition emotions in youth footballers: A three-wave longitudinal test of the mediating role of perfectionistic cognitions. *Journal of Sport and Exercise Psychology, 41*(5), 309-319. https://doi.org/10.1123/jsep.2018-0317

Draper, N., Jones, G. A., Fryer, S., Hodgson, C., & Blackwell, G. (2008). Effect of an on-sight lead on the physiological and psychological responses to rock climbing. *Journal of sports science & medicine, 7*(4), 492–498. https://pubmed.ncbi.nlm.nih.gov/24149956

Dupee, M., Forneris, T., & Werthner, P. (2016). Perceived outcomes of a biofeedback and neurofeedback training intervention for optimal performance: Learning to enhance self-awareness and self-regulation with olympic athletes. *The Sport Psychologist, 30*(4), 339-349. https://doi.org/10.1123/tsp.2016-0028

Edvardsson, A., Ivarsson, A., & Johnson, U. (2012). Is a cognitive-behavioural biofeedback intervention useful to reduce injury risk in junior football players? *Journal of sports science & medicine, 11*(2), 331–338. https://pubmed.ncbi.nlm.nih.gov/24149207

Estrada, O., Pérez, E. A., Álvarez, M. A., & Morales, M. (2012). El estilo de respuestas psicofisiológicas ante el recuerdo de situaciones adversas en deportistas (estudio piloto). In H. Gundlach, E. Pérez-Córdoba, M. Sinatra, & G. Tanucci (Eds.), *L'arte del Movimiento* (pp. 163–182). Prensa.

Fernández, P., Livacic-Rojas, P., & Vallejo, G. (2007). Cómo elegir la mejor prueba estadística para analizar un diseño de medidas repetidas. *International Journal of Clinical and Health Psychology, 7*(1), 153-175. https://www.redalyc.org/pdf/337/33770111.pdf

Firth-Clark, A., Sütterlin, S., & Lugo, R. G. (2019). Using cognitive behavioural techniques to improve academic achievement in student-athletes. *Education Sciences, 9*(2), 89. https://doi.org/10.3390/educsci9020089

Fletcher, D., Hanton, S., Mellalieu, S. D., & Neil, R. (2012). A conceptual framework of organizational stressors in sport performers. *Scandinavian journal of medicine & science in sports, 22*(4), 545-557. https://doi.org/10.1111/j.1600-0838.2010.01242.x

Garcia-Mas, A., Palou, P., Smith, R., Ponseti, X., Almeida, H. G. L. d., Lameiras, J., Jiménez, R., & Leiva, A. (2011). Ansiedad competitiva y clima motivacional en jóvenes futbolistas de competición, en relación con las habilidades y el rendimiento percibido por sus entrenadores. *Revista de psicología del deporte, 20*, 197-207. http://hdl.handle.net/10400.12/2532

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*(2), 95-112. https://doi.org/10.1007/BF02289823

Kerson, C., Sherman, R. A., & Kozlowski, G. P. (2009). Alpha suppression and symmetry training for generalized anxiety symptoms. *Journal of Neurotherapy, 13*(3), 146-155. https://doi.org/10.1080/10874200903107405

Labrador, F. J., Cruzado, J. A., & Múñoz, M. (1995). *Manual de técnicas de Modificación y terapia de conducta*. Pirámide.

Mabweazara, S. Z., Leach, L., & Andrews, B. S. (2017). Predicting swimming performance using state anxiety. *South african journal of psychology, 47*(1), 110-120. https://doi.org/10.1177/0081246316645060

Márquez, S. (1995). Beneficios psicológicos de la actividad física. *Revista de psicología general y aplicada: Revista de la Federación Española de Asociaciones de Psicología, 48*(1), 185-206. https://dialnet.unirioja.es/descarga/articulo/2378944.pdf

Mauchly, J. W. (1940). Significance test for sphericity of a normal n-variate distribution. *The Annals of Mathematical Statistics, 11*(2), 204-209. https://doi.org/10.1214/aoms/1177731915

Nestoriuc, Y., Martin, A., Rief, W., & Andrasik, F. (2008). Biofeedback treatment for headache disorders: a comprehensive efficacy review. *Applied psychophysiology and biofeedback, 33*(3), 125-140. https://doi.org/10.1007/s10484-008-9060-3

Oudejans, R. R., & Pijpers, J. R. (2010). Training with mild anxiety may prevent choking under higher levels of anxiety. *Psychology of Sport and Exercise, 11*(1), 44-50. https://doi.org/10.1016/j.psychsport.2009.05.002

Pons, J., Ramis, Y., Garcia-Mas, A., De la Llave, A. L., & Pérez-Llantada, M. (2016). Percepción de la ansiedad competitiva en relación al nivel de cooperación y compromiso deportivo en jugadores de baloncesto de formación. *Cuadernos de psicología del deporte, 16*(3), 45-54. https://revistas.um.es/cpd/article/view/278421

Pop-Jordanova, N., & Chakalaroska, I. (2008). Comparison of biofeedback modalities for better achievement in high school students. *Macedonian Journal of Medical Sciences, 1*(2), 25-30. https://doi.org/10.3889/MJMS.1857-5773.2008.0020

Pusenjak, N., Grad, A., Tusak, M., Leskovsek, M., & Schwarzlin, R. (2015). Can biofeedback training of psychophysiological responses enhance athletes' sport performance? A practitioner's perspective. *The Physician and sportsmedicine, 43*(3), 287-299. https://doi.org/10.1080/00913847.2015.1069169

Raymond, J., Sajid, I., Parkinson, L. A., & Gruzelier, J. H. (2005). Biofeedback and dance performance: A preliminary investigation. *Applied psychophysiology and biofeedback, 30*(1), 65-73. https://doi.org/10.1007/s10484-005-2175-x

Rijken, N. H., Soer, R., de Maar, E., Prins, H., Teeuw, W. B., Peuscher, J., & Oosterveld, F. G. (2016). Increasing performance of professional soccer players and elite track and field athletes with peak performance training and biofeedback: a pilot study. *Applied psychophysiology and biofeedback, 41*(4), 421-430. https://doi.org/10.1007/s10484-016-9344-y

Sheard, M., & Golby, J. (2010). Personality hardiness differentiates elite-level sport performers. *international Journal oF sport and exercise psychology, 8*(2), 160-169. https://doi.org/10.1080/1612197X.2010.9671940

Šidák, Z. (1967). Rectangular confidence regions for the means of multivariate normal distributions. *Journal of the American Statistical Association, 62*(318), 626-633. https://doi.org/10.1080/01621459.1967.10482935

Šniras, Š., & Ušpurienė, A. B. (2018). Assessment of pre-competition emotional states of different mastery women-basketball players. *Physical education of students*, *22*(3), 151-158. https://doi.org/10.15561/20755279.2018.0307

Spielberger, C. D. (1972). Anxiety as an emotional state. In C. D. Spielberger (Ed.), *Anxiety and Bahavior* (pp. 23-49). Academic Press.

Strahler, K., Ehrlenspiel, F., Heene, M., & Brand, R. (2010). Competitive anxiety and cortisol awakening response in the week leading up to a competition. *Psychology of sport and exercise*, *11*(2), 148-154. https://doi.org/10.1016/j.psychsport.2009.10.003

Taylor, J. B., Nguyen, A.-D., Paterno, M. V., Huang, B., & Ford, K. R. (2017). Real-time optimized biofeedback utilizing sport techniques (ROBUST): a study protocol for a randomized controlled trial. *BMC musculoskeletal disorders*, *18*(1), 1-13. https://doi.org/10.1186/s12891-017-1436-1

Valiente, L., & Ortís, L. C. (1994). La biorretroalimentación de la frecuencia cardíaca como técnica psicológica para mejorar el rendimiento fisiológico: un estudio piloto. *Revista de Psicología del Deporte*, *3*(1), 15-31. https://portalrecerca.uab.cat/en/publications/la-biorretroalimentaci%C3%B3n-de-la-frecuencia-card%C3%ADaca-como-t%C3%A9cnica-p

Vila, J., & Guerra, P. (2009). *Una introducción a la psicofisiología clínica*. Madrid: Ed. Pirámide.

Weinberg, R. S., & Gould, D. (2010). *Fundamentos De Psicologia Del Deporte Y Del Ejercicio Fisico/Fundamentals of Sport Psychology and Physical Exercise*. Ed. Médica Panamericana. https://www.casadellibro.com/libro-fundamentos-de-psicologia-del-deporte-y-del-ejercicio-fisico-4-ed/9788498352078/1654344